

## DESCRIPTION

## INFORMATION SECURITY APPARATUS AND INFORMATION SECURITY SYSTEM

Technical Field

5 The present invention relates to a technique for realizing safe and secure transmission and reception of contents.

Background Art

When a terminal device uses services provided by a contents provider, the terminal device and a server belonging to the 10 contents provider perform two-way authentication. If the two-way authentication succeeds, the terminal device and the server share a private key, and thereby establish a so-called SAC (Secure Authentication Channel), which is a secure data transmission channel. The terminal device and the server 15 transmit and receive contents to and from each other via the SAC. Such a technique is disclosed by Patent Document 1.

In recent years, the number of contents service providers has been increasing. Therefore, there are demands for a system 20 that supports the case where one terminal device uses services provided by a plurality of contents providers.

Patent Document 1

Japanese Laid-open Patent Document No.11-234259.

Disclosure of the Invention

The present invention therefore aims to provide an 25 information security apparatus and an information security system that are suitable for the case where one terminal device uses services provided by a plurality of contents providers.

The object can be achieved by an information security apparatus that manages information in a safe and reliable manner based on a complexity of an inverse operation on a set of integers that satisfy a condition, the information security apparatus comprising: a private key generating unit operable to generate a private key; a parameter receiving unit operable to receive parameters which respectively determine conditions; and a public key generating unit operable to generate, with use of the private key, public keys from sets of integers that satisfy the conditions determined by the parameters.

With the stated structure, the information security apparatus generates the plurality of the public keys from the private key. Therefore, in the case of generating the plurality of the public keys, the structure has an advantage that the number of the keys that should be generated and managed becomes fewer than that of the conventional device in which the private key and the public key correspond to each other on a one-to-one basis.

Here, the information security apparatus may be connected to servers via a network, the parameters may be received from the servers respectively and be different from each other, and the public key generating unit may generate public keys which are different from each other, with use of the respective parameters.

With the stated structure, the information security apparatus can generate the different public keys from the one private key by receiving the different parameters from the respective servers. Therefore, the structure has an advantage

that the number of the keys that should be generated and managed becomes fewer than that of the conventional device, which generates a pair of the private key and the public key for each server with which the device communicates.

5       Here, the information security apparatus may further comprise: a public key transmission unit operable to transmit the public keys to respective source servers that are sources of the respective parameters; a public key certification receiving unit operable to receive public key certifications 10 from the respective servers, each public key certification including each public key and a signature of each server; and a key storage unit operable to store the private key and the public key certifications.

With the stated structure, the number of the keys that 15 the key storage unit of the information security apparatus stores becomes fewer than the that of the conventional device, which stores a pair of the private key and the public key for each server with which the device communicates. This means that the capacity of the storage area can be reduced, and therefore the 20 cost can be reduced.

Here, the information security apparatus may further comprise: a contents request unit operable to read out one of the public key certifications from the key storage unit, and transmit a contents request that includes the read-out public 25 key certification to a source server that has issued the read-out public key certification; and a contents acquiring unit operable to acquire contents from the source server in a safe and reliable

manner with use of the private key and the public key included in the read-out public key certification.

With the stated structure, the information security apparatus can receive contents from the corresponding server 5 in the secure manner, by selecting one public key certification from the stored plurality of the public key certifications, and using the one private key and the public key that is included in the selected public key certification.

Here, the contents acquiring unit may include: an 10 authenticating unit operable to transmit, to the source server, signature data that is generated with use of the private key and to be authenticated by the source server with use of the public key, and authenticate the source server; a key sharing unit operable to share key information with the source server 15 if the authentication performed by the authentication unit succeeds; a receiving unit operable to receive encrypted contents, which are encrypted based on the key information, from the source server; and a decrypting unit operable to decrypts the encrypted contents based on the key information.

With the stated structure, the information security apparatus can establish a secure data transmission channel with the server, by performing two-way authentication with the server and sharing the key information in the secure manner after the authentication.

25 Here, the key storage unit may be a portable memory card that is inserted in the information security apparatus, the public key generating unit may write the private key and the

public key certifications into the portable memory card, and the portable memory card may include a secure storage area that is secure against tampering and cryptanalysis from outside, and stores the private key in the secure storage area.

5 With the stated structure, the storage device included in the information security apparatus is realized by the portable memory card. The information security apparatus can hold the private key in the secure manner by storing the private key in the tamper-resistant module included in the memory card.

10 Here, the information security apparatus may further comprise: a memory card authenticating unit operable to authenticate the memory card when the memory card is inserted into the information security apparatus; and a write-inhibit unit operable to inhibit the public key generating unit from 15 writing the private key and the public key certifications into the memory card if the authentication performed by the memory card authenticating unit fails.

With the stated structure, the information security apparatus writes the private key and the public key 20 certifications in the memory card only when the authentication of the memory card succeeds. Therefore, the structure prevents the private key from being written into an unauthorized memory card and exposed.

Here, security of the information security apparatus may 25 be based on an elliptic curve discrete logarithm problem, the parameter receiving unit may receive parameters that constitute an elliptic curve, and the public key generating unit may generate

the public keys by performing, for each parameter, a multiplication with use of the elliptic curve on the private key.

With the stated structure, the information security apparatus can acquire contents in the safe and secure manner by using the elliptic curve cryptosystem that provides high security.

Here, security of the information security apparatus may be based on an RSA cryptosystem, the private key generating unit may generate a private key  $d$ , the parameter receiving unit may receive sets of prime numbers ( $P, Q$ ) as the parameters, and the public key generating unit may generate sets of the public keys ( $N, e$ ) by calculating  $N=PQ$  and further calculating  $e$  from  $ed \equiv 1 \pmod{(P-1)(Q-1)}$ , for each set of the prime numbers.

With the stated structure, the information security apparatus uses the RSA cryptosystem as the public key cryptosystem, and therefore the present invention can be realized with a general-purpose computer system.

## 20 Brief Description of the Drawings

FIG.1 shows a structure of an information security system 1;

FIG.2 is a functional block diagram showing a structure of a terminal device 10;

25 FIG.3A shows a data structure of a password table 120;

FIG.3B shows a data structure of a CRL 130;

FIG.4 is a functional block diagram showing a structure

of a memory card 20;

FIG.5 is a functional block diagram showing a structure of a server 30;

FIG.6 is a flowchart showing overall operations performed by an information security system 1, the flowchart continuing to FIG.15;

FIG.7 is a flowchart showing operations performed by a terminal device 10 for authenticating a memory card 20;

FIG.8 is a flowchart showing operations performed by Certification Authority (CA) and each device (a terminal device, a server 30, a server 40 and a server50) for issuing a public key certification;

FIG.9A shows a data structure of a public key certification 140 (*Cert\_0010*);

FIG.9B shows a data structure of a public key certification 150 (*Cert\_0030*);

FIG.9C shows a data structure of a public key certification 160 (*Cert\_0040*);

FIG.9D shows a data structure of a public key certification 20 170 (*Cert\_0050*);

FIG.10 is a flowchart showing operations performed by a terminal device 10 and servers at the time of service subscription and registration, the flowchart continuing to a flowchart in FIG.11;

FIG.11 is a flowchart showing operations performed by a terminal device 10 and servers at the time of service subscription and registration, the flowchart being continued from FIG.10;

FIG.12A shows a data structure of a public key certification 210 (*Cert\_A*) that is issued by a server 30 to a terminal device 10;

5 FIG.12B shows a data structure of a public key certification 220 (*Cert\_B*) that is issued by a server 40 to a terminal device 10;

FIG.12C shows a data structure of a public key certification 230 (*Cert\_C*) that is issued by a server 50 to a terminal device 10;

10 FIG.13 is a flowchart showing operations for SAC establishment processing performed by a terminal device 10 and servers at the time of service subscription and registration, the flowchart continuing to FIG.14;

15 FIG.14 is a flowchart showing operations for SAC establishment processing performed by a terminal device 10 and servers at the time of service subscription and registration, the flowchart being continued from FIG.13;

20 FIG.15 is a flowchart showing overall operations performed by an information security system 1, the flowchart being continued from FIG.6;

25 FIG.16 is a flowchart showing operations for SAC establishment processing performed by a terminal device 10 and servers at the time of service usage, the flowchart being continued from FIG.17;

FIG.17 is a flowchart showing operations for SAC establishment processing performed by a terminal device 10 and servers at the time of service usage, the flowchart being

continued from FIG.16 and continuing to FIG.18;

FIG.18 is a flowchart showing operations for SAC establishment processing performed by a terminal device 10 and servers at the time of service usage, the flowchart being  
5 continued from FIG.17; and

FIG.19 is a flowchart showing operations performed by Certification Authority for generating system parameters for an elliptic curve.

10 Best Mode for Carrying Out the Invention

An information security system 1 as an embodiment of the present invention is described here. The information security system 1 is a system in which one terminal device uses services provided by a plurality of contents providers.

15 The following describe the information security system 1, with reference to drawings.

Structure

FIG.1 shows a structure of an information security system  
1. As shown in FIG.1, the information security system 1 includes  
20 a terminal device 10, a memory card 20, a server 30, a server 40 and a server 50. The memory card 20 is to be used after inserted into a memory card slot of the terminal device 10. The terminal device 10 and the servers 30, 40 and 50 are connected to each other via a network 60. The network 60 is, for instance, the  
25 Internet.

The terminal device 10 and the memory card 20 belong to a user who uses contents distribution services, and each of

servers 30, 40 and 50 belongs to a different contents provider. The content providers provide the user with the contents distribution services.

The terminal device 10, the memory card 20, and the servers

5 30, 40 and 50 deal with contents in a safe and secure manner.

Therefore, these devices are sometimes generically called an information security apparatus.

#### 1. Terminal Device 10

The structure of the terminal device 10 is described next  
10 in detail.

FIG.2 is a functional block diagram that shows the structure of the terminal device 10 functionally. As shown in FIG.2, the terminal device 10 includes a communication unit 101, an operation input unit 102, a control unit 103, a memory card input/output unit 104, a memory card authentication unit 105, a CRL storage unit 106, a public key encryption unit 107, a storage unit 108 and a reproduction unit 109.

The terminal device 10 is, more specifically, a computer system that includes a microprocessor, a ROM, a RAM, a hard disk, 20 a drive unit, a network connection unit, an MPEG decoder, an MPEG encoder, a memory card slot, and so on.

##### (1) Communication Unit 101

The communication unit 101 is a network connection unit including a web browser. The communication unit 101 is connected  
25 to the servers 30, 40 and 50 via the network 60.

The communication unit 101 receives information from the server 30 via the network 60, and outputs the received information

to the control unit 103. The communication unit 101 also receives information from the control unit 103, and outputs the received information to the server 30 via the network 60. In the same way, the communication unit 101 receives information from the 5 server 40 via the network 60, and outputs the received information to the control unit 103. The communication unit 101 also receives information from the control unit 103, and outputs the received information to the server 40 via the network 60. In the same way, the communication unit 101 receives information from the 10 server 50 via the network 60, and outputs the received information to the control unit 103. The communication unit 101 also receives information from the control unit 103, and outputs the received information to the server 50 via the network 60.

Here, the information that the communication unit 101 15 transmits to each server is, more specifically, a service subscription request, a service usage request, signature data used for establishing SAC between the terminal device 10 and each server, key information, and so on. The information that the communication unit 101 receives from each server is, more 20 specifically, signature data used for establishing SAC with each server, key information, system parameters for an elliptic curve, contents transmitted from each server after authentication and key sharing are performed, and so on.

Further, the communication unit 101 is connected to a 25 Certification Authority (hereinafter called the "CA") via the network 60. The communication unit 101 transmits and receives information to and from the CA in the following manner.

The communication unit 101 keeps CRL (Certification Revocation List), which is received from the CA, up to date all the time, and stores the received up-to-date CRL in the CRL storage unit 106 via the control unit 103. The CRL is described later.

5         The communication unit 101 receives a public key "PK\_0010" from the public key encryption unit 107 via the control unit 103, and transmits the received public key to the CA. The communication unit 101 also receives a public key certification "Cert\_0010" that corresponds to the public key "PK\_0010" from  
10 the CA, and outputs the received public key certification to the control unit 103.

In this Description, "the system parameters for the elliptic curve" are "a" and "b" that are included in the elliptic curve  $E$ :  $y^2=x^3+ax^2+b$ , a prime number "p", an order of the prime number p "q", and an arbitrary point (base point) "G" on the elliptic curve  $E$ .

#### (2) Operation input unit 102

The operation input unit 102 includes, for instance, buttons used for receiving operations from the user. Upon  
20 receiving an operation from the user, the operation input unit 102 generates an operation signal corresponding to the received operation, and outputs the generated operation signal to the control unit 103.

Here, the operation signal is, more specifically, a signal  
25 representing the service subscription request, a signal representing the service usage request, and so on.

#### (3) Control Unit 103

The control unit 103 includes a microprocessor, a ROM, a RAM and so on. The control unit 103 controls the entire terminal device 10 by performing the following processing with use of the microprocessor that executes a computer program.

- 5       (a) Receiving a signal indicating that an insertion of the memory card 20 is detected from the memory card input/output unit 104, the control unit 103 outputs an instruction to the memory card authentication unit 105 to perform authentication of the memory card 20.
- 10      (b) Upon receiving a signal representing "authentication OK" from the memory card authentication unit 105, the control unit 103 receives the public key certification from the CA. More specifically, the control unit 103 transmits a public key "PK\_0010" that is output by the public key encryption unit 107, 15 and a device ID "ID\_0010" of the control unit 103 itself prestored in the control unit 103, to the CA via the communication unit 101. The control unit 103 receives a public key certification "Cert\_0010" corresponding to the public key "PK\_0010" from the CA via the communication unit 101, and outputs the received public 20 key certification to the memory card 20 via the memory card input/output unit 104.
- 25      (c) The control unit 103 receives an operation signal from the operation input unit 102, and performs proces sing according to the received operation signal.
- For instance, upon receiving, from the operation input unit 102, an operation signal indicating the service subscription request for subscribing the services provided by the server 30,

the server 40 or the server 50, the control unit 103 outputs an instruction to the memory card input/output unit 104 to read out the public key certification "Cert\_0010" from the memory card 20, outputs an instruction to the public key encryption unit 107 to establish the SAC, and outputs an instruction to the public key encryption unit 107 to perform the service subscription.

Upon receiving, from the operation input unit 102, a signal indicating the service usage request for using the services provided by the server 30, the server 40 or the server 50, the control unit 103 outputs an instruction to the memory card input/output unit 104 to read out a private key for service SK and the public key certification received from the server corresponding to the request from the memory card 20. Further, the control unit 103 outputs an instruction to the public key encryption unit 107 to establish the SAC, and outputs the instruction to the public key encryption unit 107 to acquire contents.

(d) After establishing the SAC between the terminal device 10 and the server 30, the server 40 or the server 50, the control unit 103 receives a session key from the public key encryption unit 107 at the time of the transmission or the reception of information between the terminal device 10 and each server. The received session key is used as an encryption key or a decryption key for encrypting information that is to be transmitted to the server or decrypting encrypted information that is received from the server.

(4) Memory Card Input/Output Unit 104

The memory card input/output unit 104 includes the memory card slot. Upon detecting that the memory card 20 is inserted into the memory card slot, the memory card input/output unit 5 outputs a signal representing the detection to the control unit 103. The memory card input/output unit 104 also performs input and output of information between the control unit 103 and the memory card 20, in the state where the memory card 20 is inserted into the memory card slot.

10 (5) Memory Card Authentication Unit 105

The memory card authentication unit 105 includes a microprocessor, a ROM, a RAM and so on. The ROM or the RAM stores a password table 120 that is shown in FIG. 3A.

The password table 120 includes one or more password 15 information sets. Each password information set includes a memory card number and an authentication password. The memory card number is used for identifying a memory card that is available in the state where it is inserted in the terminal device 10. The authentication password is shared between the terminal device 20 10 and the memory card that is identifiable with the memory card number corresponding to the authentication password. The authentication password is 256-bit data that is used for authenticating the memory card.

Receiving the signal indicating that the memory card 20 25 is inserted into the memory card input/output unit 104 from the control unit 103, the memory card authentication unit 105 reads out a password information set 121 corresponding to the memory

card 20 from the password table 120, and further reads out an authentication password  $PW_0$  from the password information set 121. The memory card authentication unit 105 also generates a 56-bit random number  $R_0$ . The memory card authentication unit 5 105 outputs the generated random number  $R_0$  to the memory card 20 via the control unit 103 and the memory card input/output unit 104. At the same time, the memory card authentication unit 105 applies an encryption algorithm  $E$  to the authentication password  $PW_0$  to generate an encrypted text  $E1$ , with use of the 10 random number  $R_0$  as an encryption key. Then, the memory card authentication unit 105 stores the generated encrypted text  $E1$ . Here, the encryption algorithm  $E$  is DES (Data Encryption Standard) for instance.

Receiving an encrypted text  $E2$  from the memory card 20 15 via the control unit 103 and the memory card input/output unit 104, the memory card authentication unit 105 compares the received encrypted text  $E2$  with the stored encrypted text  $E1$ . If the  $E1$  is identical with the  $E2$ , the memory card authentication unit 105 outputs a signal representing "authentication OK" to 20 the control unit 103, and if the  $E1$  is different from the  $E2$ , the memory card authentication unit 105 outputs a signal representing "authentication NG" to the control unit 103.

#### (6) CRL Storage Unit 106

The CRL storage unit 106 includes a RAM, and stores therein 25 a CRL. The CRL is a list of invalidated devices, such as a device that has performed unauthorized operations and a device whose private key has been exposed.

The CRL is managed by the CA. The terminal device 10 receives the CRL from the CA via the network 60, and stores the CRL in the CRL storage unit 106. Here, the terminal device 10 keeps the CRL received from the CA up to date all the time. The 5 terminal device 10 replaces the old CLR already stored in the CRL storage unit 106 with the up-to-date CRL.

The details of the CRL are disclosed in: American National Standards Institute, American National Standard for Financial Services, ANSX9.57: Public Key Cryptography for the Financial 10 Industry: Certificate Management, 1997.

(7) Public Key Encryption Unit 107

The public key encryption unit 107 includes a microprocessor, a ROM, a RAM, a random number generator, and so on.

15 At the time of transmitting the service subscription request to the servers 30, 40 and 50, the public key encryption unit 107 performs processing for establishing the SAC with each server. Also, at the time of transmitting the service usage request to the servers 30, 40 and 50, the public key encryption 20 unit 107 performs processing for establishing the SAC with each server. The public key cryptosystem used here is the elliptic curve cryptosystem and the RSA cryptosystem.

Elliptic Curve Discrete Logarithm Problem

25 The elliptic curve discrete logarithm problem, which is used as a basis for security of the elliptic curve cryptosystem, is described next.

Assume that  $E(GF(p))$  is an elliptic curve defined over

a finite field  $GF(p)$ , with a base point  $G$  on the elliptic curve  $E$  being set as a base point when the order of the elliptic curve  $E$  is exactly divided by a large prime. In this case, the discrete logarithm problem is to compute an integer  $x$ , if any, that  
5 satisfies the equation;

$y=x*G$ , where  $y$  is a given element on the elliptic curve  $E$ .

Here,  $p$  is a prime and  $GF(p)$  is a finite field that includes  $p$  elements. In this Description, the symbol "\*" represents  
10 repeated additions of an element included in the elliptic curve, and " $x*G$ " means to add the base point  $G$  included in the elliptic curve  $x$  times, in the manner shown by the next equation;

$$x*G=G+G+G+\dots+G.$$

The security of the public key cryptosystem is based on  
15 the discrete logarithm problem, because the discrete logarithm problem for the finite field  $GF(p)$  including a large number of elements is extremely difficult.

The details of the discrete logarithm problem are disclosed in: Neal Koblitz, "A Course in Number Theory and Cryptography",  
20 Springer-Verlag, 1987.

#### Description of Calculation Formula Using Elliptic Curve

The calculation using the elliptic curve is described next.

The elliptic curve is defined by

$$y^2=x^3+ax+b,$$

25 where the coordinates of arbitrary points  $P$  and  $Q$  are respectively  $(x_1, y_1)$  and  $(x_2, y_2)$ . Here, the coordinates of a point  $R$  that is defined by " $R=P+Q$ " are  $(x_3, y_3)$ .

If  $P \neq Q$ , " $R=P+Q$ " becomes an add operation. The following are the formulas for the add operation:

$$x_3 = \{(y_2 - y_1) / (x_2 - x_1)\}^2 - x_1 - x_2,$$

$$y_3 = \{(y_2 - y_1) / (x_2 - x_1)\} (x_1 - x_3) - y_1.$$

5 If  $P=Q$ ,  $R=P+Q=P+P=2\times P$ . Therefore, " $R=P+Q$ " becomes a double operation. The following are the formulas for the double operation;

$$x_3 = \{(3x_1^2 + a) / 2y_1\}^2 - 2x_1,$$

$$y_3 = \{(3x_1^2 + a) / 2y_1\} (x_1 - x_3) - y_1.$$

10 Note that the operations described above are operations on the finite field over which the elliptic curve is defined. The details of the calculation formula using the elliptic curve is described in "Efficient Elliptic Curve Exponentiation" in Miyaji, Ono and Cohen, Advances in Cryptology-Proceedings of ICICS'97, Lecture Notes in Computer Science, pp.282-290, Springer-Verlag, 1997)

#### Service Subscription Request

The following describes the public key encryption unit 107 at the time when the terminal device 10 transmits the service 20 subscription request to the server 30. The public key encryption unit 107 receives the random number  $R\_0010$  from the control unit 103, and stores therein the received random number. The random number  $R\_0010$  is a private key of the terminal device 10 itself, and used for establishing the SAC. Note that the random number 25  $R\_0010$  is stored in a secure area of the memory card 20, and it is read out from the control unit 103 via the memory card input/output unit 104. The public key encryption unit 107 uses

the RSA cryptosystem as the algorithm for the public key cryptosystem, and establishes the SAC between the terminal device 10 and the server 30. The details are described later. Using the SAC, the public key encryption unit 107 receives system parameters for the elliptic curve " $a_1$ ,  $b_1$ ,  $p_1$ ,  $q_1$  and  $G_1$ " from the server 30 via the network 60, the communication unit 101 and the control unit 103. As specific examples, the following values are given as the parameters.

$a_1 = -3$

10            $b_1 = 16461$

$p_1 = 20011$

$q_1 = 20023$

$G_1 = (1, 7553)$ .

Further, the public key encryption unit 107 generates the private key for service  $SK$ . The public key encryption unit 107 calculates a public key  $PK_A = SK * G_1 \pmod{p_1}$  with use of the generated private key for service  $SK$  and the system parameters. The public key encryption unit 107 stores the generated  $SK$  in the memory card 20 via the control unit 103 and the memory card input/output unit 104, and transmits the calculated public key  $PK_A$  to the server 30 via the control unit 103, communication unit 101 and the network 60 with use of the SAC that is established with the server 30.

The following describe the public key encryption unit 107 at the time when the terminal device 10 transmits the service subscription request to the server 40. The public key encryption unit 107 receives the random number  $R\_0010$ , which is the private

key of the terminal device 10 itself, from the control unit 103, and establishes the SAC with the server 40 with use of the RSA cryptosystem. Upon establishing the SAC, the public key encryption unit 107 receives the private key for service *SK* from the control unit 103, and receives system parameters for the elliptic curve " $a_2$ ,  $b_2$ ,  $p_2$ ,  $q_2$  and  $G_2$ " from the server 40 via the network 60, the communication unit 101 and the control unit 103 with use of the SAC that is established with the server 40.

As specific examples, the following values are given as the parameters.

$a_2 = -3$

$b_2 = 16461$

$p_2 = 20011$

$q_2 = 20023$

$G_2 = (18892, 5928)$ .

The public key encryption unit 107 calculates a public key  $PK_B = SK * G_2 \pmod{p_2}$  based on the received *SK* and system parameters, and transmits the calculated public key *PK\_B* to the server 40 via the control unit 103, the communication unit 101 and the network 60 with use of the SAC that is established with the server 40.

The following describe the public key encryption unit 107 at the time when the terminal device 10 transmits the service subscription request to the server 50. The public key encryption unit 107 receives the random number *R\_0010*, which is the private key of the terminal device 10 itself, from the control unit 103, and establishes the SAC with the server 50 with use of the RSA

cryptosystem. Upon establishing the SAC, the public key encryption unit 107 receives the *SK* from the control unit 103, and receives system parameters for the elliptic curve " $a_3$ ,  $b_3$ ,  $p_3$ ,  $q_3$  and  $G_3$ " from the server 50 via the network 60, the communication unit 101 and the control unit 103 with use of the SAC that is established with the server 50.

As specific examples, the following values are given as the parameters.

$$a_3 = -3$$

10            $b_3 = 16461$

$$p_3 = 20011$$

$$q_3 = 20023$$

$$G_3 = (8898, 13258).$$

The public key encryption unit 107 calculates a public key  $PK_C = SK * G_3 \pmod{p_3}$  based on the *SK* and the system parameters, and transmits the calculated public key *PK\_C* to the server 50 via the control unit 103, the communication unit 101 and the network 60 with use of the SAC that is established with the server 50.

20           As described above, the terminal device 10 generates the three public keys *PK\_A*, *PK\_B* and *PK\_C* which correspond to the servers on a one-to-one basis, with use of the one private key for service *SK* that is generated at the time of transmitting the service subscription request to the server 30 and the respective sets of system parameters received from the servers. Here, among the sets of system parameters respectively received from the servers, the base points  $G_1$ ,  $G_2$  and  $G_3$  are different

from each other, and therefore the three public keys generated by the terminal device 10 are different from each other.

Service Usage Request

The following describe the public key encryption unit 107 at the time when the terminal device 10 transmits the service usage request to the server 30. The public key encryption unit 107 receives the *SK*, *Cert\_A* and *Pk\_30* from the control unit 103, and establishes the SAC with the server 30 with use of the elliptic curve cryptosystem as the algorithm of the public key cryptosystem. The *SK* is a private key for service for the terminal device 10, and it is stored in the secure area of the memory card 20. The *Cert\_A*, which is illustrated in FIG.12A, is a public key certification issued to the terminal device 10 from the server 30. The *Cert\_A* includes the public key *PK\_A* that is released by the terminal device 10 to the server 30, and signature data generated by the server 30. The *Cert\_A* is stored in a public key storage area 204c of the memory card 20. The *Pk\_30* is a public key of the server 30, and it is stored in the storage unit 108. The details of the processing for establishing the SAC are described later.

The following describe the public key encryption unit 107 at the time when the terminal device 10 transmits the service usage request to the server 40. The public key encryption unit 107 receives the *SK*, *Cert\_B* and *Pk\_40* from the control unit 103, and establishes the SAC with the server 40 with use of the elliptic curve cryptosystem as the algorithm of the public key cryptosystem. The *Cert\_B*, which is illustrated in FIG.12B, is

a public key certification issued to the terminal device 10 from the server 40. The *Cert\_B* includes the public key *PK\_B* that is released by the terminal device 10 to the server 40, and signature data generated by the server 40. The *Cert\_B* is stored 5 in the public key storage area 204c of the memory card 20. The *Pk\_40* is a public key of the server 40, and it is stored in the storage unit 108.

The following describe the public key encryption unit 107 at the time when the terminal device 10 transmits the service 10 usage request to the server 50. The public key encryption unit 107 receives the *SK*, the *Cert\_C* and the *Pk\_50* from the control unit 103, and establishes the SAC with the server 50 with use of the elliptic curve cryptosystem as the algorithm of the public key cryptosystem. The *Cert\_C*, which is illustrated in FIG.12C, 15 is a public key certification issued to the terminal device 10 from the server 50. The *Cert\_C* includes the public key *PK\_C* that is released by the terminal device 10 to the server 50, and signature data generated by the server 50. The *Cert\_C* is stored in the public key storage area 204c of the memory card 20. The *Pk\_50* is a public key of the server 50, and it is stored 20 in the storage unit 108.

#### (8) Storage Unit 108

The storage unit 108 receives the public keys *Pk\_30*, *Pk\_40* and *Pk\_50* from the control unit 103, stores the received public 25 keys. The *Pk\_30* is the public key of the server 30. The *Pk\_40* is the public key of the server 40. The *Pk\_50* is the public key of the server 50.

(9) Reproduction Unit 109

The reproduction unit 109 includes an audio recorder, a video recorder, a buffer, and so on. As shown in FIG.2, the reproduction unit 109 is connected to an external output device, 5 and outputs decoded contents to the external output device. The output device is, more specifically, a monitor and a speaker.

2. Memory Card 20

The memory card 20 is a memory that is in the shape of a card and uses a flash memory as a recording medium. FIG.4 10 is a functional block diagram showing the structure of the memory card 20 functionally. As shown in FIG.4, the memory card 20 includes an input/output unit 201, a memory control unit 202, an authentication unit 203 and a memory 204.

(1) Input/Output Unit 201

15 The input/output unit 201 includes a plurality of pin terminals. In the state where the memory card 20 is inserted in the memory card input/output unit 104 of the terminal device 10, the input/output unit 201 outputs data received from the memory card input/output unit 104 to the memory control unit 202 20 and outputs data received from the memory control unit 202 to the memory card input/output unit 104 with use of the plurality of the pin terminals.

For instance, when the memory card 20 is inserted in the terminal device 10, the input/output unit 201 receives the memory 25 card number "20" that is stored in the authentication unit 203 via the memory control unit 202, and outputs the received memory card number "20" to the memory card input/output unit 104. The

data that is transmitted or received by the input/output unit 201 is described later in the sections that describe the operations performed by the information security system 1.

(2) Memory Control Unit 202

5       The memory control unit 202 reads out data from the memory 204 according to instructions received from the terminal device 10 via the input/output unit 201. Then, the memory control unit 202 outputs the read-out data to the terminal device 10 via the input/output unit 201. The memory control unit 202 also receives  
10 data from the terminal device 10 via the input/output unit 201, and stores the received data in the memory 204.

The memory control unit 202 receives the random number  $R_0$  from the terminal device 10 via the input/output unit 201, and outputs the received random number  $R_0$  to the authentication unit 203. The memory control unit 202 also receives the encrypted text  $E2$ , and outputs the received  $E2$  to the input/output unit 201 to the terminal device 10 via the input/output unit 201.  
15

(3) Authentication Unit 203

The authentication unit 203 includes a microprocessor, a ROM, a RAM, and so on. The ROM or the RAM stores computer programs for the authentication, and the microprocessor executes the programs. Note that the ROM prestores the memory card number "20" and the authentication password " $PW_0$ ". The memory card number "20" is used for identifying the memory card 20. The  
20  $PW_0$  is a secret data that is shared between the authentication unit 203 and the terminal device 10 and used for challenge-response type authentication performed between the  
25

authentication unit 203 and the memory card authentication unit 105 of the terminal device 10.

The authentication unit 203 receives the random number  $R\_0$  from the terminal device 10 via the input/output unit 201, 5 and applies the encryption algorithm  $E$  to the authentication password  $PW\_0$  to generate the encrypted text  $E2$ , with use of the received random number  $R\_0$  as the private key. The authentication unit 203 outputs the generated encrypted text  $E2$  to the terminal device 10 via the memory control unit 202 10 and the input/output unit 201.

Here, the encryption algorithm  $E$  is, for instance, a DES.

#### (4) Memory 204

The memory 204 is, more specifically, a storage device that is structured by an EEPROM and so on. The memory 204 includes 15 a secure area 204a, a contents storage area 204b and the public key storage area 204c.

The secure area 204a is a temper-resistant storage area that is physically or logically protected against inside analysis and tampering. The secure area 204a stores therein the  $R\_0010$  20 that is the private key of the terminal device 10, and the private key for service  $SK$ . Note that the storage capacity of the secure area 204a is extremely small compared to the entire storage capacity of the memory 204.

The content storage area 204b stores the contents that 25 are acquired by the terminal device 10 from the server 30, the server 40 and the server 50.

The public key storage area 204c stores therein the public

key certification *Cert\_0010* acquired from the CA, the public key certification *Cert\_A* acquired from the server 30, the public key certification *Cert\_B* acquired from the server 40, and the public key certification *Cert\_C* acquired from the server 50.

5    3. Server 30

The server 30 is a device that belongs to a contents provider. Upon receiving the service subscription request from the terminal device 10 that is connected to the server 30 via the network 60, the server 30 registers the terminal device 10. Upon 10 receiving the service usage request from the terminal device 10 that is already registered, the server 30 provides contents to the terminal device 10.

FIG. 5 is a functional block diagram that shows functionally shows the structure of the server 30. As shown in FIG. 5, the 15 server 30 includes a communication unit 301, a control unit 302, a CRL storage unit 303, a Cert management unit 304, a registration information management unit 305, a public key encryption unit 306, and a contents storage unit 307.

The server 30 is, more specifically, a computer system 20 that includes a microprocessor, a ROM, a RAM, a hard disk unit and so on.

(1) Communication unit 301

The communication unit 301 is a unit that is used for a network connection and includes a Web browser. The communication 25 unit 301 is connected to the terminal device 10 via the network 60.

The communication unit 301 receives information from the

terminal device 10, and outputs the received information to the control unit 302. The communication unit 301 also receives information from the control unit 302 and outputs the received information to the terminal device 10.

5       The information that the communication unit 301 receives from the terminal device 10 is, more specifically, the public key *PK\_A*, the signature data used for establishing the SAC, key information, and so on. The information that the communication unit 301 outputs to the terminal device 10 is, more specifically,  
10      the public key certification *Cert\_A*, the signature data used for establishing the SAC, key information, the system parameters for the elliptic curve, contents, and so on.  
15

Further, the communication unit 301 is connected to the CA via the network 60, and transmits/receives information to/from  
15      the CA in the following manner.

The communication unit 301 constantly receives up-to-date CRL from the CA via the network 60, and stores the received CRL in the CRL storage unit 303 via the control unit 302.

20      The communication unit 301 receives a public key "PK\_0030" from the public key encryption unit 306 via the control unit 302, and outputs the received public key to the CA via the network 60. The communication unit 301 also receives a public key certification "Cert\_0030" that corresponds to the public key "PK\_0030" from the CA via the network 60, and outputs the received  
25      public key certification to the control unit 302.

The communication unit 301 acquires the system parameters for the elliptic curve from the CA via the network 60, and outputs

the acquired system parameters to the control unit 302.

(2) Control Unit 302

The control unit 302 includes a microprocessor, a ROM, a RAM. The control unit 103 controls the entire server 30 with 5 use of the microprocessor that executes computer programs.

(a) Before the control unit 302 communicates with the terminal device 10, a public key certification is issued to the control unit 302 by the CA. More specifically, the communication unit 301 transmits the public key "PK\_0030" that is output by the 10 public key encryption unit 306 and a device ID of the control unit 302 "ID\_0030" that is prestored in the control unit 302 to the CA via communication unit 301. The control unit 302 receives the public key certification "Cert\_0030" that corresponds to the public key "PK\_0030" from the CA via the 15 communication unit 301, and outputs the received public key certification to the Cert management unit 304.

(b) Upon receiving the service subscription request form the terminal device 10, the control unit 302 reads out the "Cert\_0030" from the Cert management unit 304. Further, the control unit 20 302 outputs instructions to the public key encryption unit 306 to establish the SAC with the terminal device 10. After the SAC is established, the control unit 302 encrypts the system parameters for the elliptic curve " $a_1$ ,  $b_1$ ,  $p_1$ ,  $q_1$  and  $G_1$ " with use of the session key received from the public key encryption 25 unit 306. The system parameters are acquired from the CA. Then, the control unit 302 transmits the encrypted system parameters to the terminal device 10 via the communication unit 301 and

the network 60.

As specific examples, the following values are given as the parameters.

$$a_1 = -3$$

5            $b_1 = 16461$

$$p_1 = 20011$$

$$q_1 = 20023$$

$$G_1 = (1, 7553).$$

(c) As a part of the processing for establishing the SAC, the  
10 control unit 302 reads out up-to-date CRL from the CRL storage  
unit 303, and judges whether the terminal device 10, which is  
the authentication target, is an invalidated device.

(d) Upon receiving the service usage request including the *Cert\_A*  
15 from the terminal device 10, the control unit 302 judges whether  
the *Cert\_A* is surely the public key certification issued to the  
terminal device 10 by the server 30 itself. Here, the control  
unit 302 refers to registration information that is managed by  
the registration information management unit 305. If the *Cert\_A*  
20 received from the terminal device 10 is correct, the control  
unit 302 instructs the public key encryption unit 306 to establish  
the SAC.

(e) After the SAC between the server 30 and the terminal device  
10 is established, for transmitting and receiving information  
to and from the terminal device 10, the control unit 302 receives  
25 the session key from the public key encryption unit 306. Using  
the received session key as an encryption key or a decryption  
key, the control unit 302 encrypts and transmits information

to the terminal device 10, and decrypts the information received from the terminal device 10. For instance, after the SAC between the server 30 and the terminal device 10 is established for providing the services, the control unit 302 receives the session key 5 from the public key encryption unit 306 and reads out the contents from the contents storage unit 307. The control unit 302 encrypts the read-out contents with use of the session key to generate encrypted contents, and transmits the generated encrypted contents to the terminal device 10 via the communication unit 301.

(3) CRL Storage Unit 303

The CRL storage unit 303 includes a RAM, and stores therein the CRL. The CRL is a list of IDs of invalidated devices, such as a device that has performed unauthorized operations and a device whose private key has been exposed. The CA transmits the CRL to the server 30 via the network 60. Here, the server 30 keeps the CRL received from the CA up to date all the time. The server 30 replaces the old CLR already stored in the CRL storage unit 303 with the up-to-date CRL. In the following descriptions, the CRL storage unit 303 stores the CRL 130 shown in FIG.3B as the up-to-date CRL, as the CRL storage unit 106 of the terminal device 10 stores.

(4) Cert management Unit 304

The Cert management Unit 304 receives the public key certification *Cert\_0030* from the CA via the communication unit 301 and the control unit 302, and stores therein the received *Cert\_0030*.

(5) Registration Information Management Unit 305

The registration information management unit 305 manages registration information regarding the terminal device to which the public key certification is issued by the public key encryption unit 306. The registration information includes the public key of a registered terminal device, a membership number that is allocated to the terminal device, information relating to the user, and so on. The registration information is used for managing the registered terminal device and user. The registration information is also used by the control unit 302 for verifying the Cert received from the terminal device 10.

(6) Public key Encryption Unit 306

The public key encryption unit 306 includes a microprocessor, a ROM, a RAM, and a random number generator.

Before the server 30 communicates with the terminal device 10, the public key encryption unit 306 generates the random number  $R_{-}0030$  with use of the random number generator, and generates the public key  $PK_{-}0030$  based on the generated random number  $R_{-}0030$ . The public key encryption unit 306 transmits the generated public key  $PK_{-}0030$  to the CA via the control unit 302 and the communication unit 301.

Registration of Terminal Device 10

The public key encryption unit 306 generates a private key  $K_{S-}30$ , and receives the system parameters for the elliptic curve from the control unit 302. The public key encryption unit 306 calculates  $K_{P-}30 = K_{S-}30 * G_1 \pmod{p_1}$  with use of the private key  $K_{S-}30$  and the system parameters, and thereby generate a public

key  $K_p$ \_30. The public key encryption unit 306 outputs the generated public key  $K_p$ \_30 to the control unit 302.

At the time of the service subscription and the registration, upon receiving the public key  $PK_A$  from the terminal device 10, the public key encryption unit 306 generates the public key certification  $Cert_A$  based on the received public key  $PK_A$ , and outputs the generated  $Cert_A$  to the control unit 302.

#### Providing Terminal Device 10 with Services

Upon receiving instructions from the control unit 302 to establish the SAC, the public key encryption unit 306 establishes the SAC with the terminal device 10, and generates the session key. The details of the SAC establishment are described later.

#### (7) Contents Storage Unit 307

The contents storage unit 307 is, more specifically, a hard disk drive unit that stores contents therein.

#### 4. Server 40

The server 40 is a device that belongs to a contents provider, which is different from the contents provider that the server 30 belongs to. Upon receiving the service subscription request from the terminal device 10 that is connected to the server 40 via the network 60, the server 40 registers the terminal device 10. The server 40 also stores therein contents. Upon receiving the service usage request from the terminal device 10 that is already registered, the server 40 provides contents to the terminal device 10. The server 40 is, more specifically, a computer system that includes a microprocessor, a ROM, a RAM,

a hard disk unit and so on. The structure of the server 40 is the same as the structure of the server 30 shown in FIG.5. Therefore, the structure of the server 40 is not illustrated here. The following mainly describe the server 40 by focusing  
5 on the difference between the server 40 and the server 30.

(a) Before communicating with the terminal device 10, the server 40 generates and transmits a public key  $PK\_0040$  to the CA, and a public key certification  $Cert\_0040$  is issued to the server 40 by the CA. The public key certification 160 in FIG.9C shows  
10 the data structure of the  $Cert\_0040$ . The  $Cert\_0040$  received from the CA is used for establishing the SAC between the terminal device 10 and the server 40.

(b) The server 40 receives the system parameters for the elliptic curves from the CA. Here, a set of the system parameters received  
15 by the server 40 is unique to the server 40.

More specifically, the server 40 receives the following system parameters:

$$a_2 = -3$$

$$b_2 = 16461$$

$$p_2 = 20011$$

$$q_2 = 20023$$

$$G_2 = (18892, 5928).$$

The server 40 generates a private key  $K_{s\_40}$ , performs the elliptic curve calculation  $K_{p\_40} = K_{s\_40} * G_2 \pmod{p_2}$  with use of  
25 the generated private key  $K_{s\_40}$  and the system parameters received from the CA, and thereby generates a public key  $K_{p\_40}$ .

After establishing the SAC with the terminal device 10,

the server 40 transmits the system parameters received from the CA and the generated public key  $K_p$ \_40 to the terminal device 10.

(c) The server 40 receives the public key  $PK_B$  from the terminal device 10, and issues the public key certification  $Cert_B$  for the received public key  $PK_B$ . A public key certification 220, which is illustrated in FIG.12B, shows the data structure of the  $Cert_B$ .

(d) Upon receiving the service usage request including the  $Cert_B$  from the terminal device 10, the server 40 verifies the  $Cert_B$ . If the verification of the  $Cert_B$  succeeds, the server 40 establishes the SAC with the terminal device 10, and outputs the contents to the terminal device 10.

##### 5. Server 50

The server 50 is a device that belongs to a contents provider, which is different from the respective contents providers that the server 30 and the server 40 belong to. Upon receiving the service subscription request from the terminal device 10 that is connected to the server 50 via the network 60, the server 50 registers the terminal device 10. The server 50 also stores therein contents. Upon receiving the service usage request from the terminal device 10 that is already registered, the server 50 provides contents to the terminal device 10. The server 50 is, more specifically, a computer system that includes a microprocessor, a ROM, a RAM, a hard disk unit and so on. The structure of the server 50 is the same as the structure of the server 30 shown in FIG.5. Therefore, the structure of the server

50 is not illustrated here. The following describe the server 50 by focusing on the difference between the server 50 and the servers 30 and 40.

(a) Before communicating with the terminal device 10, the server 5 50 generates and transmits a public key  $PK\_0050$  to the CA, and a public key certification  $Cert\_0050$  is issued to the server 50 by the CA. The public key certification 170 in FIG. 9D shows the data structure of the  $Cert\_0050$ . The  $Cert\_0050$  received from the CA is used for establishing the SAC with the terminal 10 device 10.

(b) The server 50 receives the system parameters for the elliptic curves from the CA. Here, a set of the system parameters received by the server 50 is unique to the server 50.

More specifically, the server 50 receives the following 15 system parameters:

$$A_3 = -3$$

$$B_3 = 16461$$

$$P_3 = 20011$$

$$Q_3 = 20023$$

$$G_3 = (8898, 13258).$$

The server 40 generates a private key  $K_{s\_50}$ , performs the elliptic curve calculation  $K_{p\_50} = K_{s\_50} * G_3 \pmod{p_3}$  with use of the generated private key  $K_{s\_50}$  and the system parameters received from the CA, and thereby generates a public key  $K_{p\_50}$ .

25 After establishing the SAC with the terminal device 10, the server 50 transmits the system parameters received from the CA and the generated public key  $K_{p\_50}$  to the terminal device

10.

(c) The server 50 receives the public key *PK\_C* from the terminal device 10, and issues the public key certification *Cert\_C* for the received public key *PK\_C*. A public key certification 230, which is illustrated in FIG.12C, shows the data structure of the *Cert\_C*.

(d) Upon receiving the service usage request including the *Cert\_C* from the terminal device 10, the server 50 verifies the *Cert\_C*. If the verification of the *Cert\_C* succeeds, the server 50 establishes the SAC with the terminal device 10, and outputs the contents to the terminal device 10.

#### Operations

Operations performed by the information security system 1 are described next.

(1) Operations by Entire System (for Service Subscription and Registration)

FIG.6 and FIG.15 are flowcharts that show the operation by the entire information security system 1. FIG.6 shows the operations by the information security system 1 at the time of "the service subscription" and "the registration". FIG.15 shows the operations by the information security system 1 at the time of "the service usage".

Firstly, when the memory card 20 is inserted into the memory card input/output unit 104 of the terminal device 10 (Step S101), the terminal device 10 authenticates the memory card 20 (Step S102). If the authentication of the memory card 20 fails (NG in Step S103), the terminal device 10 finishes the processing.

If the authentication of the memory card 20 succeeds (OK in Step S103), the public key certification is issued by the CA to the terminal device 10 (Step S104).

The public key certification is previously issued by the CA to the server 30 (Step S105). In the same way, the public key certification is previously issued by the CA to the server 40 (Step S106). In the same way, the public key certification is previously issued by the CA to the server 50 (Step S107).

Next, the terminal device 10 and the server 30 perform the service subscription and the registration (Step S108). Next, the terminal device 10 and the server 40 perform the service subscription and the registration (Step S109). Next, the terminal device 10 and the server 50 perform the service subscription and the registration (Step S110).

These are the processing for "the service subscription" and "the registration".

The processing is continued to FIG.15. However, for the sake of convenience, the details of the processing for the service subscription and the registration are described first with reference to the flowcharts in FIG.7 and later, and then, FIG.15 is described.

#### (2) Authentication of Memory Card 20

Here, the authentication of the memory card 20 is described, with reference to the flowchart shown in FIG.7. Note that the details of the operations performed in Step S102 in FIG.6 are described here.

In the state where the memory card 20 is inserted in the

memory card input/output unit 104 of the terminal device 10, the memory card authentication unit 105 of the terminal device 10 generates the random number  $R_0$  (Step S201) and holds therein the generated random number  $R_0$ . At the same time, the memory card authentication unit 105 also outputs the generated random number  $R_0$  to the memory card 20 via the memory card input/output unit 104, and the memory card 20 receives the random number  $R_0$  (Step S202).

Upon receiving the random number  $R_0$  via the input/output unit 201 and the memory control unit 202, the authentication unit 203 of the memory card 20 applies the encryption algorithm  $E$  to the authentication password  $PW_0$ , which is stored in the authentication unit 203, to generate the encrypted text  $E2$ , with use of the random number  $R_0$  as the encryption key (Step S203). Meanwhile, the memory card authentication unit 105 applies the encryption algorithm  $E$  to the authentication password  $PW_0$ , which is shared between the memory card 20 and the memory card authentication unit 105, to generate the encrypted text  $E1$ , with use of the random number  $R_0$  that is generated in Step S201 as the private key (Step S204).

The authentication unit 203 of the memory card 20 transmits the encrypted text  $E2$ , which is generated in Step S203, to the terminal device 10, and the terminal device 10 receives the encrypted text  $E2$  (Step S205). The memory card authentication unit 105 of the terminal device 10 receives the encrypted text  $E2$  via the memory card input/output unit 104 and the control unit 103, and compares the received encrypted text  $E2$  to the

encrypted text  $E_1$  which is generated in Step S204 (Step S206).

If the encrypted text  $E_1$  is the same as the encrypted text  $E_2$  (YES in Step S207), this means that the terminal device 10 has succeeded to authenticate the memory card 20, and the memory card authentication unit 105 outputs a signal representing "authentication OK" to the control unit 103 (Step S208). Then, the terminal device 10 goes back to Step S103 in FIG.6, and continues the processing.

If the encrypted text  $E_1$  is not the same as the encrypted text  $E_2$  (NO in Step S207), this means that the terminal device 10 has failed to authenticate the memory card 20, and the memory card authentication unit 105 outputs a signal representing "authentication NG" to the control unit 103 (Step S209). Then, the terminal device 10 goes back to Step S103 in FIG.6, and continues the processing.

(3) Processing for Receiving Public Key Certification (Cert) from CA

Here, the processing for the terminal device 10 and the servers 30, 40 and 50 to respectively receive the public key certifications from the CA is described with use reference to the flowchart shown in FIG.8. Note that the details of the operations performed in Steps 104, 105, 106 and 107 in FIG.6 are described here.

The public key encryption unit of each of the terminal device 10 and servers 30, 40 and 50 generates a random number  $R_L$  by the random number generator of each (Step S301), and further generates a public key  $PK_L$  from the generated random number

5         $R_L$  (Step S302). Here,  $L=0010$  is given for the terminal device 10,  $L=0030$  is given for the server 30,  $L=0040$  is given for the server 40 and  $L=0050$  is given for the server 50. Note that an algorithm used for generating the public key  $PK_L$  from the random number  $R_L$  is not limited here. As an example, the RSA cryptosystem may be used.

10      The public key encryption unit of each of the terminal device 10 and servers 30, 40 and 50 outputs the generated public key  $PK_L$  to each control unit. Each control unit transmits the public key  $PK_L$  and the information that includes the device ID of the control unit itself and stored in the control unit, to the CA via the communication unit. The CA receives the public key  $PK_L$  and information that includes the device ID from each. (Step S303).

15      As to the source of the information received in Step S303 (request source of the public key certification), the CA verifies the existence and correctness of the public key, the mail address, the user, and the organization that the user belongs to (Step S304).

20      If the request source is not authorized (NO in Step S305), the CA finishes the processing.

25      If the request source is authorized, (YES in Step S305), the CA adds signature data  $Sig_LCA$  to the received public key  $PK_L$  and device ID, and generates a public key certification  $Cert_L$  (Step S306). The CA transmits the generated public key certification  $Cert_L$  to each of the request sources, namely the terminal device 10 and the servers 30, 40 and 50. Each of the

terminal device 10 and the servers 30, 40 and 50 receives the public key certification *Cert\_L* (Step S307).

The terminal device 10 stores the received public key certification *Cert\_0010* in the public key storage area 204c of the memory card 20 via the control unit 103 and the memory card input/output unit 104 (Step S308). Here, the data structure of the public key certification *Cert\_0010*, which the terminal device 10 receives from the CA, is shown in FIG. 9A. As shown in FIG. 9A, the *Cert\_0010* includes the *ID\_0010*, the *PK\_0010* and the *Sig\_0010CA*. Note that the *ID\_0010* is the device ID of the terminal device 10.

The server 30 stores the public key certification *Cert\_0030* received in Step S307 in the Cert management unit 304 via the control unit 302 (Step S308). FIG. 9B shows the data structure of the public key certification *Cert\_0030* that the server 30 receives from the CA. As shown in FIG. 9B, the *Cert\_0030* includes the *ID\_0030*, the *PK\_0030* and the *Sig\_0030CA*. Note that the *ID\_0030* is the device ID of the server 30.

In the same way, the server 40 and the server 50 store the public key certifications *Cert\_0040* and the *Cert\_0050* inside respectively (Step S308). FIG. 9C shows the data structure of the public key certification *Cert\_0040* that the server 40 receives from the CA. FIG. 9D shows the data structure of the public key certification *Cert\_0050* that the server 50 receives from the CA.

Upon receiving the public key certification from the CA, the terminal device 10 and the server 30 start the processing

in Step S108. The server 40 starts the processing in Step S109, and the server 50 starts the processing in Step S110.

(4) Service Subscription and Registration

With reference to the flowcharts shown in FIG.10 and FIG.11, the following describe the service subscription and the registration between the terminal device 10 and the server 30 (Step S108 in FIG.6), the service subscription and the registration between the terminal device 10 and the server 40 (Step S109 in FIG.6), and the service subscription and the registration between the terminal device 10 and the server 50 (Step S110 in FIG.6). In this section, each of the servers 30, 40 and 50 is sometimes simply called "the server".

After the service subscription request is caused to the server by the terminal device 10 receiving an input from the user via the operation input unit 102 (Step S401), the SAC is established between the terminal device 10 and the server (Step S402).

The server receives the system parameters for the elliptic curve from the CA (Step S403). Here, the system parameters that the server 30 acquires from the CA are " $a_1, b_1, p_1, q_1$  and  $G_1$ ", and the system parameters that the server 40 acquires from the CA are " $a_2, b_2, p_2, q_2$  and  $G_2$ ", and the system parameters that the server 40 acquires from the CA are " $a_3, b_3, p_3, q_3$  and  $G_3$ ".

The control unit of the server encrypts the acquired system parameters with use of the session key as the encryption key, which is shared between the terminal device 10 and the server in the SAC establishment processing in Step S402 (Step S404).

Note that the encryption algorithm used here is, for instance, the DES (Data Encryption Standard). The control unit of the server transmits the encrypted system parameters to the terminal device via the communication unit and the network 60, and the 5 communication unit 101 of the terminal device 10 receives the system parameters (Step S405).

The control unit 103 of the terminal device 10 decrypts the encrypted system parameters with use of the session key as the decryption key, which is shared between the terminal device 10 and the server in the SAC establishment processing in Step S402 (Step S406). If the public key encryption unit 107 of the terminal device 10 has already generated the private key for service *SK*, and the secure area 204a of the memory card 20 stores the *SK* (YES in Step S407), the processing goes to Step S409. 15 If the public key encryption unit 107 of the terminal device 10 has not generated the private key for service *SK* yet, and the secure area 104a of the memory card 20 does not store the *SK* (NO in Step S407), the public key encryption unit 107 generates the private key for service with the random number generator 20 (Step S408).

The public key encryption unit 107 generates a public key *PK\_N* by calculating the next equation with use of the private key for service *SK* and the system parameters acquired from the server (Step S409).

25  $PK_N = SK * G \pmod{p}$ , where  $N = A, B$  and  $C$ .

Note that private key for service *SK* is the key data generated in Step S408, or the key data that has been already

generated and stored in the secure area 204a of the memory card 20.

The  $PK_A$  is the public key that is generated based on the system parameters received from the server 30. The  $PK_B$  is the 5 public key that is generated based on the system parameters received from the server 40. The  $PK_C$  is the public key that is generated based on the system parameters received from the server 50.

Next, the control unit 103 of the terminal device 10 10 encrypts the generated public key  $PK_N$  with user of the session key as the encryption key (Step S410) and transmits the encrypted  $PK_N$  to the server via the communication unit 101 and the network 60, and the communication unit of the server receives the encrypted public key  $PK_N$ . (Step S411). The control unit of 15 the server decrypts the encrypted public key  $PK_N$  with use of the session key (Step S412).

Next, the public key encryption unit of the server generates a public key certification  $Cert_N$  for the public key  $PK_N$  received from the terminal device 10 (Step S413). Then, 20 the public key encryption unit generates a private key  $K_{s\_M}$  ( $M=30, 40$  and  $50$ ) with use of the random number generator, and calculates a public key  $K_{p\_M}=K_{s\_M}*G$  based on the generated private key  $K_{s\_M}$  (Step S415). The sign  $G$  represents the base point of the elliptic curve. The control unit of the server encrypts the public key 25 certification  $Cert_N$  and the public key  $K_{p\_M}$  with use of the session key as the encryption key and transmits the encrypted  $Cert_N$  and  $K_{p\_M}$  to the terminal device 10 via the communication

unit and the network 60, and the communication unit 101 of the terminal device 10 receives the encrypted *Cert\_N* and *K<sub>P</sub>\_M* (Step S417).

The control unit 103 of the terminal device 10 decrypts 5 the received *Cert\_N* and *K<sub>P</sub>\_M* with use of the session key (Step S418), stores the decrypted public key certification *Cert\_N* in the secure area 204a of the memory card 20 via the memory card input/output unit 104 (Step S419) and stores the public key *K<sub>P</sub>\_M* of the server in the storage unit 108 (Step S420).

Meanwhile, the registration information management unit 10 of the server generates the registration information regarding the terminal device 10 and manages the registration information (Step S421). The registration information includes the public key of the terminal device and the membership number allocated 15 to the terminal device 10, and so on.

The public key certification *Cert\_N*, which each server generates and issues to the terminal device 10, is described next, with reference to FIG.12.

FIG.12A shows the data structure of the *Cert\_A*, which is 20 issued by the server 30 to the terminal device 10. As shown in FIG.12A, the *Cert\_A* includes a service ID "SID\_0123A", a membership number "NO\_0001", a public key "PK\_A" and signature data "Sig\_A".

The service ID "SID\_0123A" represents a type of the service 25 that the terminal device 10 used among the services that the server 30 provides. The membership number "NO\_0001" is the number allocated to the terminal device in order to identify

the terminal device from a plurality of terminal devices that are registered at the server 30. The public key "PK\_A" is the key data generated by the terminal device 10 based on the system parameters for the elliptic curve, which are received from the 5 server 30, and the private key for service SK. The signature data "Sig\_A" is data that the server 30 generates by applying the signature algorithm to the "SID\_0123A", the "NO\_0001" and the "PK\_A".

FIG.12B shows the data structure of the Cert\_B, which is 10 issued by the server 40 to the terminal device 10. As shown in FIG.12B, the Cert\_B includes a service ID "SID\_0321B", a membership number "NO\_0025", a public key "PK\_B" and signature data "Sig\_B".

The service ID "SID\_0321B" represents a type of the service 15 that the terminal device 10 used among the services that the server 40 provides. The membership number "NO\_0025" is the number allocated to the terminal device in order to identify the terminal device from a plurality of terminal devices that are registered at the server 40. The public key "PK\_B" is the 20 key data generated by the terminal device 10 based on the system parameters for the elliptic curve, which are received from the server 40, and the private key for service SK. The signature data "Sig\_B" is data that the server 40 generates by applying the signature algorithm to the "SID\_0321B", the "NO\_0025" and 25 the "PK\_B".

FIG.12C shows the data structure of the Cert\_C, which is issued by the server 50 to the terminal device 10. As shown

in FIG.12C, the *Cert\_C* includes a service ID "SID\_0132C", a membership number "NO\_3215", a public key "PK\_C" and signature data "Sig\_C".

The service ID "SID\_0132C" represents a type of the service  
5 that the terminal device 10 used among the services that the server 50 provides. The membership number "NO\_3215" is the number allocated to the terminal device in order to identify the terminal device from a plurality of terminal devices that are registered at the server 50. The public key "PK\_C" is the  
10 key data generated by the terminal device 10 based on the system parameters for the elliptic curve, which are received from the server 50, and the private key for service SK. The signature data "Sig\_C" is data that the server 50 generates by applying the signature algorithm to the "SID\_0132C", the "NO\_3215" and  
15 the "PK\_C".

#### (5) Establishment of SAC 1

Here, the operations for establishing the SAC between the terminal device 10 and each server at the time of the service subscription and the registration are described, with reference  
20 to the flowcharts shown in FIG.13 and FIG.14. Note that the details of Step S402 in FIG.10 are described here.

Here, *Gen()* is a key generation function, and Y is a parameter unique to the system.  $\text{Gen}(X, \text{Gen}(Y, Z)) = \text{Gen}(Y, \text{Gen}(X, Z))$  is satisfied. The key generation function is not described  
25 here, because it can be realized with a technique in the public domain.

First, the control unit 103 of the terminal device 10 reads

out the public key certification *Cert\_0010* from the memory card 20 via the memory card input/output unit 104 (Step S501). The communication unit 101 of the terminal device 10 transmits the *Cert\_0010* to the server via the network 60, and the communication 5 unit of the server receives the *Cert\_0010* (Step S502). The server applies a signature verification algorithm to the signature data *Sig\_0010CA* included in the public key certification *Cert\_0010* with use of a public key *PK\_CA* of the CA (Step S503). Here, assume that the public key *PK\_CA* of the CA is already known by 10 the server. If the verification fails (NO in Step S504), the server finishes the processing. If the verification succeeds (YES in Step S504), the control unit of the server reads out the CRL from the CRL storage unit (Step S505), and judges whether the *ID\_0010* included in the public key certification *Cert\_0010* 15 is listed in the CRL.

If it is judged that the *ID\_0010* is listed in the CRL (YES in Step S506), the server finishes the processing. If it is judged that the *ID\_0010* is not listed in the CRL (NO in Step S506), the control unit of the server reads out the public key 20 certification *Cert\_L* from the Cert management unit (Step S507). The control unit transmits the public key certification *Cert\_L* to the terminal device 10 via the communication unit and the network 60, and the communication unit of the terminal device 10 receives the *Cert\_L* (Step S508).

25 Upon receiving the public key certification *Cert\_L*, the control unit 103 of the terminal device 10 applies a signature verification algorithm to the signature data *Sig\_LCA* included

in the *Cert\_L* with use of a public key *PK\_CA* of the CA (Step S509). Here, assume that the public key *PK\_CA* of the CA is already known by the terminal device 10. If the verification fails (NO in Step S510), the terminal device 10 finishes the processing.

- 5 If the verification succeeds (YES in Step S510), the control unit 103 reads out the CRL from the CRL storage unit 106 (Step S511), and judges whether the received *ID\_L* that is included in the public key certification *Cert\_L* is listed in the CRL.

If it is judged that the *ID\_L* is listed in the CRL (YES 10 in Step S512), the terminal device 10 finishes the processing. If it is judged that the *ID\_L* is not listed in the CRL (NO in Step S512), the terminal device 10 continues the processing.

After the processing in Step S507, the public key encryption unit of the server generates a random number *Cha\_B* 15 (Step S513). The communication unit of the server transmits the random number *Cha\_B* to the terminal device 10 via the network 60, and the communication unit 101 of the terminal device 10 receives the random number *Cha\_B* (Step S514).

Upon receiving the random number *Cha\_B*, the control unit 20 103 of the terminal device 10 reads out the private key *R\_0010* from the secure area 204a of the memory card 20 via the memory card input/output unit 104, and outputs the read-out private key *R\_0010* and the received random number *Cha\_B* to the public key encryption unit 107. The public key encryption unit 107 25 applies the signature algorithm to the random number *Cha\_B* with use of the private key *R\_0010*, to generate the signature data *Sig\_a* (Step S515). The communication unit 101 transmits the

signature data *Sig\_a* generated by the public key encryption unit 107 to the server via the network 60, and the communication unit of the server receives the signature data *Sig\_a* (Step S516).

Upon receiving the signature data *Sig\_a* via the control unit, the public key encryption unit of the server applies the signature verification algorithm to the signature data *Sig\_a* with use of the public key *PK\_0010* that is included in the *Cert\_0010* and received in Step S502 (Step S517). If the verification fails (NO in Step S518), the server finishes the processing. If the verification succeeds (YES in Step S518), the server continues the processing.

Meanwhile, following the processing in Step S515, the terminal device 10 generates the random number *Cha\_A* by the public key encryption unit 107 (Step S519). The public key encryption unit 107 transmits the generated random number *Cha\_A* to the server via the control unit 103, the communication unit 101 and the network 60, and the communication unit of the server receives the random number *Cha\_A* (Step S520).

The control unit of the server outputs the received random number *Cha\_A* to the public key encryption unit, and the public key encryption unit applies the signature algorithm to the received random number *Cha\_A* with use of the private key *R\_L* that is stored inside the public key encryption unit, and thereby generate the signature data *Sig\_b* (Step S521). The server transmits the generated signature data *Sig\_b* to the terminal device 10 via the control unit, the communication unit and the network 60, and the communication unit 101 of the terminal device

10 receives the signature data *Sig\_b* (Step S522).

Upon receiving the signature data *Sig\_b* via the control unit 103, the public key encryption unit 107 of the terminal device 10 applies the signature verification algorithm to the 5 signature data *Sig\_b* with use of the public key *PK\_L* that is included in the *Cert\_L* and received in Step S508 (Step S523). If the verification fails (NO in Step S524), the terminal device 10 finishes the processing. If the verification succeeds (YES in Step S524), the public key encryption unit 107 of the terminal 10 device 10 generates a random number "a" (Step S525), and generates *Key\_A=Gen(a, Y)* with use of the generated random number "a" (Step S526). The communication unit 101 of the terminal device 10 transmits the *Key\_A* generated by the public key encryption unit 107 to the server via the network 60, and the communication unit 15 of the server receives the *Key\_A* (Step S527).

Upon receiving the *Key\_A*, the public key encryption unit of the server generates a random number "b" (Step S528), and generates *Key\_B=Gen(b, Y)* with use of the generated random number "b" (Step S529). The communication unit of the server transmits 20 the *Key\_B* generated by the public key encryption unit to the terminal device 10 via the network 60, and the communication unit of the terminal device 10 receives the *Key\_B* (Step S530). The public key encryption unit of the server also generates *Key\_AB=Gen(b, Key\_A)=Gen(b, Gen(a, Y))* with use of the random 25 number "b" generated in Step S528 and the *Key\_A* received in Step S527 (Step S531), and outputs the generated *Key\_AB* to the control unit as the session key (Step S532).

Then, the server goes back to Step S403 shown in FIG.10, and continues the processing.

Meanwhile, upon receiving the *Key\_B* in Step S530, the public key encryption unit 107 of the terminal device 10 generates 5 *Key\_AB*=*Gen(a, Key\_B)*=*Gen(a, Gen(b, Y))* based on the *Key\_B* and the random number "a" that is generated in Step S525, and outputs the generated *Key\_AB* as the session key to the control unit 103 (Step S534). Then, the terminal device 10 goes back to Step S406 in FIG.10 and continues the processing.

10 (6) Operations by Entire System 2 (for Service Usage)

The operations performed by the entire information security system 1 are described next with reference to the flowchart shown in FIG.15, which is continued from FIG.6. Note that the operations shown in FIG.15 are the operations for the 15 "service usage" among the operations performed by the entire information security system 1. In this section, each of the servers 30, 40 and 50 is sometimes simply called "the server".

After the service usage request is caused to the server by the terminal device 10 receiving an input from the user via 20 the operation input unit 102 (Step S601), the control unit 103 reads out the public key certification *Cert\_N* (*N=A, B or C*) that is generated by the server specified by the user, from the secure area 204a of the memory card 20 via the memory card input/output unit 104 (Step S602). The control unit 103 transmits the read-out 25 public key certification *Cert\_N* to the specified server via the communication unit 101 and the network 60, and the communication unit of the server receives the public key certification *Cert\_N*.

(Step S603).

Upon receiving the public key certification *Cert\_N*, the control unit of the server judges whether the received *Cert\_N* is correct in the following manner (Step S604). The control 5 unit reads out the registration information corresponding to the terminal device 10 from the registration management unit, and judges whether the service ID, the membership number and the public key of the terminal device 10 are the same as the registered information. Further, the control unit outputs the 10 signature data *Sig\_N* included in the *Cert\_N* to the public key encryption unit. Upon receiving the *Sig\_N*, the public key encryption unit applies the signature verification algorithm to the received *Sig\_N* to verify the *Sig\_N*, and outputs the verification result.

15 If the verification of the *Cert\_N* fails (NG in Step S605), the server finishes the processing. If the verification of the *Cert\_N* succeeds (OK in Step S605), the server and the terminal device 10 perform processing for establishing the SAC (Step S606).

20 After the SAC is established with the terminal device 10, the control unit of the server reads out the contents from the contents storage unit (Step S607), and encrypts the read-out contents with use of the session key as the encryption key, which is shared with the terminal device 10 in Step S606 (Step S608).

25 The encryption algorithm used here is, for instance, the DES. The communication unit of the server transmits the encrypted contents to the terminal device 10 via the network 60, and the

communication unit 101 of the terminal device 10 receives the encrypted contents (Step S609).

Upon receiving the encrypted contents, the control unit 103 of the terminal device 10 decrypts the received contents 5 with use of the session key as the decrypt key, which is shared with the server in Step S606 (Step S610). The control unit 103 stores the decrypted contents in the contents storage area 204b of the memory card 20 via the memory card input/output unit 104 (Step S611).

10 (7) Establishment of SAC 2

Here, the operations for establishing the SAC between the terminal device 10 and each server at the time of the service usage, with reference to the flowcharts shown in FIG.16, FIG.17 and FIG.18. Note that the details of Step S606 in FIG.15 are 15 described here.

Here,  $\text{Gen}()$  is a key generation function, and  $Y$  is a parameter unique to the system.  $\text{Gen}(X, \text{GEN}(Y, Z)) = \text{Gen}(Y, \text{Gen}(X, Z))$  is satisfied.

First, the control unit 103 of the terminal device 10 reads 20 out the public key certification *Cert\_0010* from the memory card 20 via the memory card input/output unit 104 (Step S701). The communication unit 101 of the terminal device 10 transmits the *Cert\_0010* to the server via the network 60, and the communication unit of the server receives the *Cert\_0010* (Step S702). The public 25 key encryption unit of the server applies a signature verification algorithm to the signature data *Sig\_0010CA* included in the public key certification *Cert\_0010* with use of a public

key *PK\_CA* of the CA (Step S703). If the verification fails (NO in Step S704), the server finishes the processing. If the verification succeeds (YES in Step S704), the control unit of the server reads out the CRL from the CRL storage unit (Step 5 S705), and judges whether the *ID\_0010* included in the public key certification *Cert\_0010* is listed in the CRL.

If it is judged that the *ID\_0010* is listed in the CRL (YES in Step S706), the server finishes the processing. If it is judged that the *ID\_0010* is not listed in the CRL (NO in Step 10 S706), the control unit of the server reads out the public key certification *Cert\_L* from the Cert management unit (Step S707). The control unit transmits the public key certification *Cert\_L* to the terminal device 10 via the communication unit and the network 60, and the communication unit of the terminal device 15 10 receives the *Cert\_L* (Step S708).

Upon receiving the public key certification *Cert\_L*, the control unit 103 of the terminal device 10 applies a signature verification algorithm to the signature data *Sig\_LCA* included in the *Cert\_L* with use of a public key *PK\_CA* of the CA, in order 20 to verify the signature (Step S709). If the verification fails (NO in Step S710), the terminal device 10 finishes the processing. If the verification succeeds (YES in Step S710), the control unit 103 reads out the CRL from the CRL storage unit 106 (Step S711), and judges whether the received *ID\_L* that is included 25 in the public key certification *Cert\_L* is listed in the CRL.

If it is judged that the *ID\_L* is listed in the CRL (YES in Step S712), the terminal device 10 finishes the processing.

If it is judged that the *ID\_L* is not listed in the CRL (NO in Step S712), the terminal device 10 continues the processing.

After the processing in Step S707, the public key encryption unit of the server generates a random number *Cha\_D* 5 (Step S713). The communication unit of the server transmits the random number *Cha\_D* to the terminal device 10 via the network 60, and the communication unit 101 of the terminal device 10 receives the random number *Cha\_D* (Step S714).

Upon receiving the random number *Cha\_D*, the public key 10 encryption unit 107 calculates

$$R1=(rx, ry)=Cha_D \cdot G \text{ (Step S715)},$$

and calculates *S* by

$S \times Cha_D = m + rx \times SK \pmod{q}$  (Step S716). Here, *q* is an order 15 of the elliptic curve *E*, *m* is a message that the terminal device transmits to the server, and *SK* is a private key for service of the terminal device 10 read out from the secure area 204a of the memory card 20 via the memory card input/output unit 104.

The terminal device generates signature data  $Sig_d = (R1, 20 S)$  from the obtained *R1* and *S* (Step S717), and outputs the generated signature data *Sig\_d* and the message *m* to the server, and the server receives the signature data *Sig\_d* and the message *m* (Step S718).

The public key encryption unit of the server calculates  
 $m \cdot G + rx \cdot PK_N,$

25 and further calculates

$$S \cdot R1 \text{ (Step S719).}$$

The public key encryption unit of the server identifies

the terminal device 10 that has transmitted the data, by judging whether  $S*R1=m*G+rx*PK_N$  is satisfied (Step S720). This equation is derivable from the following.

$$\begin{aligned} S*R1 &= \{(m+rx*SK)/Cha_D\} * Cha_D * G \\ 5 &= (m+rx*SK) * G \\ &= m*G + (rx*SK) * G \\ &= m*G + rx*PK_N. \end{aligned}$$

If  $S*R1 \neq m*G+rx*PK_N$  (NO in Step S720), the server finishes the processing. If  $S*R1=m*G+rx*PK_N$  (YES in Step S720), the 10 server continues the processing.

Meanwhile, after the terminal device 10 transmits the *Sig\_d* and the *m* to the server in Step S718, the public key encryption unit 107 generates a random number *Cha\_E* (Step S721), outputs the generated random number *Cha\_E* to the server via the control 15 unit 103, the communication unit 101 and the network 60, and the communication unit of the server receives the *Cha\_E* (Step S722).

Upon receiving the random number *Cha\_E* via the control unit, the public key encryption unit of the server calculates 20  $R2=(rx, ry)=Cha_E*G$  (Step S723),

and also calculates  $S'$  by

$$S' \times Cha_E = m' + rx \times Ks_M \pmod{q} \quad (\text{Step S724}).$$

Here, the  $m'$  is a message that the server transmits to the terminal device 10, and the  $Ks_M$  ( $M=30, 40$  or  $50$ ) is the private key of 25 the server. More specifically,  $Ks_{30}$  is the private key of the server 30,  $Ks_{40}$  is the private key of the server 40, and  $Ks_{50}$  is the private key of the server 50.

The server generates signature data  $Sig_e=(R2, S')$  from the obtained  $R2$  and  $S'$  (Step S725), and outputs the generated signature data  $Sig_e$  and the message  $m'$  to the terminal device 10, and the terminal device receives the signature data  $Sig_e$  and the message  $m'$  (Step S726).

5 The public key encryption unit 107 of the terminal device calculates

$$m' * G + rx * Kp_M \text{ (Step S731).}$$

Here, the  $Kp_M$  ( $M=30, 40$  or  $50$ ) is the public key of each server 10 generated by calculating  $Kp_M = Ks_M * G$ . More specifically,  $Kp_{30}$  is the public key of the server 30,  $Kp_{40}$  is the public key of the server 40 and  $Kp_{50}$  is the public key of the server 50.

15 The public key encryption unit 107 further calculates  $S' * R2$  (Step S731).

The public key encryption unit 107 identifies the terminal device 10 that has transmitted the data, by judging whether  $S' * R2 = m' * G + rx * Kp_M$  is satisfied (Step S732). This equation is derivable from the following.

$$\begin{aligned} 20 \quad S' * R2 &= \{ ((m' + rx * Ks_M) / Cha_E) * Cha_E \} * G \\ &= (m' + rx * Ks_M) * G \\ &= m' * G + (rx * Ks_M) * G \\ &= m' * G + rx * Kp_M. \end{aligned}$$

If  $S' * R2 \neq m' * G + rx * Kp_M$  (NO in Step S732), the terminal device 25 10 finishes the processing. If  $S' * R2 = m' * G + rx * Kp_M$  (YES in Step S732), the public key encryption unit 107 generates a random number "d" (Step S733), and generates  $Key_D = Gen(d, Y)$  with use

of the generated random number "d" (Step S734). The communication unit 101 of the terminal device 10 transmits the *Key\_D* generated by the public encryption unit 107 to the server via the network 60, and the communication unit of the server 5 receives the *Key\_D* (Step S735).

Upon receiving the *Key\_D*, the public key encryption unit of the server generates a random number "e" (Step S736), and generates  $\text{Key}_E = \text{Gen}(e, Y)$  with use of the generated random number "e" (Step S737). The communication unit of the server outputs 10 the *Key\_E* generated by the public encryption unit to the terminal device 10 via the network 60, and the communication unit of the terminal device 10 receives the *Key\_E* (Step S738). The public key encryption unit of the server generates  $\text{Key}_{DE} = \text{Gen}(e, \text{Key}_D) = \text{Gen}(e, \text{Gen}(d, Y))$  with use of the random number "e" 15 generated in Step S735 and *Key\_D* received in Step S735 (Step S741), and outputs the generated *Key\_{DE}* as the session key to the control unit (Step S742). After that, the server goes back to Step S607 in FIG.15 and continues the processing.

Meanwhile, upon receiving the *Key\_E* in Step S378, the 20 public key encryption unit 107 of the terminal device 10 generates  $\text{Key}_{DE} = \text{Gen}(d, \text{Key}_E) = \text{Gen}(d, \text{Gen}(e, Y))$  from the *Key\_E* and the random number "d" that is generated in Step S733 (Step S739), and outputs the generated *Key\_{DE}* as the session key to the control 25 unit 103 (Step S740). After that, the terminal device 10 goes back to Step S610 in FIG.15, and continues the processing.

(7) Operations for Generating System Parameters for Elliptic Curve

In the information security system 1, the Certification Authority (CA) has a function for issuing the public key certification to each device, and a function for generating system parameters that are suitable for the encryption, and 5 transmitting the generated system parameters to each server. Here, "system parameters for the elliptic curve" represents "a" and "b" included in the elliptic curve  $E: y^2=x^3+ax+b$ , a prime number "p", an order of p "q", and a base point "G" on the elliptic curve  $E$ . Especially in this system, the CA generates a unique 10 set of the parameters for each server.

The operations performed by the CA for generating the system parameters for the elliptic curve, with reference to a flowchart shown in FIG.19.

An elliptic curve management device included in the CA 15 generates a random number (Step S801), generates the a, the b, the prime number q, and the base point G, which determine the elliptic curve (Step S802), and calculates the order of the elliptic curve with use of the generated parameters (Step S803).

Next, with use of the derived order, the security of the 20 elliptic curve is judged by judging whether the following conditions for a secure elliptic curve are satisfied.

If the elliptic curve is on a finite field, the conditions for the elliptic curve to be secure against all existing cryptanalysis are:

25 (Condition 1) The order of the elliptic curve is not p, not  $p-1$  and not  $p+1$ .

(Condition 2) The order of the elliptic curve has a large prime

number.

According to "Encryption, Zero Knowledge Interactive Proof, and Arithmetic" (pp.155-156, supervised by Information Processing Society of Japan, edited by Tatsuaki Ohta and Kazuo 5 Ohta, Kyoritsu Shyuppan co.,Ltd, 1995), if the conditions above are satisfied, exponential time is required for breaking the encryption regarding the largest prime number of the order.

If the condition 1 and the condition 2 are not satisfied (NG in Step S804), the processing goes back to Step S801, and 10 repeats the generation of the random number, generation of the system parameters for the elliptic curve, the calculation of the order of the elliptic curve, and the judgment of the conditions.

If the condition 1 and the condition 2 are satisfied (OK 15 in Step S804), the elliptic curve management device compares the newly generated system parameters to the already generated and stored system parameters (Step S805). If the newly generated set of the parameters is the same as any set of the already stored system parameters (YES in Step S806), the elliptic curve 20 management device discards the generated system parameters (Step S807), goes back to Step S801 and continues the processing.

If the newly generated set of the parameters is not the same as any set of the already stored system parameters (NO in Step S806), the elliptic curve management device stores the newly 25 generated sets of the system parameters, and at the same time, transmits those parameters to the servers 30, 40 or 50 (Step S808).

Note that the elliptic curve management device performs the above-described processing every time the elliptic curve management device receives the request from the servers 30, 40 or 50.

5 This allows each of the servers 30, 40 and 50 to acquire a unique set of the system parameters for the elliptic curve.

<Summary>

As described above, in the present invention, it is assumed that the public key cryptosystem used for the SAC is the elliptic 10 curve cryptosystem, for instance. In the elliptic curve cryptosystem, the public key is calculated after the private key is generated. The private key and the system parameters are used for calculating the public key, and when the private key is the same, different public keys will be generated if the 15 system parameters are different.

In the present invention, the server that provides the contents distribution services transmits the system parameters, which is for the service of the server itself, to the terminal device that uses the services. If there are a plurality of such 20 servers that provide the contents distribution services, the terminal device acquires different set of the system parameters from each server.

The terminal device calculates the public key from the private key that is already stored in the terminal device and 25 the received parameters, and transmits the calculated public key to the server. The server that receives the public key generates the public key certification by adding a signature

to the public key, and returns the public key certification to the terminal device.

#### Modifications

The present invention is described above according to the embodiments of the present invention. However, the present invention is not limited to the above-described embodiments, as a matter of course. The following modifications are included in the present invention.

(1) In the above-described embodiments, among the system parameters for the elliptic curve, which the terminal device 10 acquires from each server, the  $G$  is different for each server. However, the present invention is not limited to this. At least the prime number  $p$  or the base point  $G$  has to be different for each server. As a matter of course, the case where each parameter included in the set of parameters is different for each server is included in the present invention. In the present invention, the object of differentiating, for each server, the set of system parameters for the elliptic curve received by the terminal device 10 is to generate different public key for each server. The differentiation of the system parameters itself is not the object of the present invention.

(2) The above-described invention has a structure in which the terminal 10 generates the public keys  $PK_A$ ,  $PK_B$  and  $PK_C$  from the private key  $SK$  and the system parameters. However, the public keys are not necessarily generated by the terminal device 10. The following cases are included in the present invention as well.

(a) The case where the server generates the public key.

Firstly, the SAC is established between the terminal device 10 and each server.

The terminal device 10 generates the private key for service  $SK$ , and transmits the generated private key for service to each server via the SAC in the safe and secure manner.

Each server generates the public key corresponding to the private key for service  $SK$  from the private key for service  $SK$  of the terminal device 10 and the system parameters for the elliptic curve acquired from the CA. Each server generates the public key certification by adding each server's own signature to the generated public key, and returns the generated public key certification to the terminal device 10.

(b) The case where the Certification Authority (CA) generates the public key.

Firstly, the SAC is established between the terminal device 10 and the CA.

The CA generates the three different sets of system parameters. The terminal device 10 generates the private key for service  $SK$ , and transmits the generated private key for service  $SK$  to the CA via the SAC in the safe and secure manner.

Upon receiving the private key  $SK$  from the terminal device 10, the CA generates three different public keys from the one private key  $SK$  and the three sets of the system parameters. The CA transmits the generated three public keys to the terminal device.

Upon receiving the three public keys, the terminal device

transmits the three public keys to the servers 30, 40 and 50 respectively. Each server receives the public key from the terminal device, and generates the public key certification by adding the signature to the received public key, and returns  
5 the generated public key certification to the terminal device  
10.

(3) The public key cryptosystem used for generating the signature data and verifying the signature data at the time of establishing the SAC is not limited to the elliptic curve cryptosystem. The  
10 structure that uses the RSA cryptosystem as the public key cryptosystem is included in the present invention. The following describes the embodiments that use the RSA cryptosystem.

#### Basic Points of RSA Cryptosystem

15 Public Key:  $N, e$

Private key:  $P, Q, d$

$$N=P \times Q, (e, (P-1)(Q-1))=1$$

$$ed \equiv 1 \pmod{(P-1)(Q-1)}$$

Encryption:  $C=E(M)=M^e \pmod{N}$

20 Decryption:  $M=D(C)=C^d \pmod{N}$

#### Operations

The following describe the operations performed by the terminal device 10 for receiving the public key certification from the server 30, the server 40 and the server 50.

25 (Step 1) The terminal device 10 selects arbitrary two large prime numbers  $P_1$  and  $Q_1$  which are different from each other. The terminal device 10 also generates a private key  $d$  by a random

number generator, and so on.

(Step 2) The terminal device 10 calculates  $N_1=P_1 \times Q_1$ . The terminal device 10 also calculates  $e_1$  from  $e_1 d \equiv 1 \pmod{(P_1-1)(Q_1-1)}$ .

5 (Step3) The terminal device 10 transmits the public key ( $N_1$ ,  $e_1$ ) to the server 30, receives the public key certification from the server 30, and stores the public key certification.

(Step4) The terminal device 10 deletes  $P_1$  and  $Q_1$  and stores the private key  $d$  in a secure storage area.

10 (Step5) The terminal device 10 selects two large prime numbers  $P_2$  and  $Q_2$  which are respectively different from  $P_1$  and  $Q_1$ .

(Step6) The terminal device 10 calculates  $N_2=P_2 \times Q_2$ . The terminal device 10 also calculates  $e_2$  from  $e_2 d \equiv 1 \pmod{(P_2-1)(Q_2-1)}$ .

15 (Step7) The terminal device 10 transmits the public key ( $N_2$ ,  $e_2$ ) to the server 40, receives the public key certification from the server 40, and stores the public key certification.

(Step8) The terminal device 10 deletes  $P_2$  and  $Q_2$ .

(Step9) The terminal device 10 selects two large prime numbers  $P_3$  and  $Q_3$  which are respectively different from  $P_1$  and  $Q_1$  and  $P_2$  and  $Q_2$ .

20 (Step10) The terminal device 10 calculates  $N_3=P_3 \times Q_3$ . The terminal device 10 also calculates  $e_3$  from  $e_3 d \equiv 1 \pmod{(P_3-1)(Q_3-1)}$ .

(Step11) The terminal device 10 transmits the public key ( $N_3$ ,  $e_3$ ) to the server 50, receives the public key certification from the server 50, and stores the public key certification.

25 (Step12) The terminal device 10 deletes  $P_3$  and  $Q_3$ .

In this way, the terminal device 10 can generate or acquire a plurality of sets of large prime numbers ( $P$ ,  $Q$ ) instead of

the system parameters for the elliptic curve, and generate a plurality of public keys ( $N, e$ ) from the one private key  $d$  and the plurality of sets of the prime numbers ( $P, Q$ ) according to the algorithm of the RSA cryptosystem. In other words, the 5 terminal device 10 can generate a plurality of public keys from one private key, establish the SAC with each server, and transmit and receive contents with use of the generated public keys not only according to the elliptic curve cryptosystem, but also according to the RSA cryptosystem.

- 10 (4) In the above-described modification that uses the RSA cryptosystem, each server may generate the public key, instead of the terminal device 10 generates the plurality of public keys.
- (5) In the embodiments, the terminal device and each server have structures in which they receive the CRL from the CA via the 15 network 60. However, the way of acquiring the CRL is not limited to this. The CRL may be received via broadcast wave, or it may be recorded on a recording medium and distributed.
- (6) The private key, the public key and the contents may be stored in a storage area in the terminal device, instead of being stored 20 in the memory card. However, at least the private key should be stored in a secure storage area.
- (7) In the above-described embodiments, the terminal device 10 has functions of generating the private key and the public key, and establishing the SAC. However, the terminal device 10 is 25 not necessarily required to perform such processing. The present invention includes cases where a memory card having IC chip (hereinafter called "the IC memory card") that is inserted

in a terminal device connected to the network performs processing of generating the private key and the public key, and establishing the SAC, and so on.

The following describes an embodiment of the present  
5 invention where the IC memory card is used.

The IC memory card is inserted in the terminal device, and it can communicate with the server 30, the server 40, and the server 50 via the terminal device.

The IC memory card includes a storage area and a control  
10 unit that is structured by an IC chip, a ROM, a RAM and so on. Note that a part of the storage area is a secure area that is secure against tampering and cryptanalysis from outside.

Previously, the IC memory card communicates with the CA via the terminal device, receives, from the CA, the public key  
15 certification that is issued by the CA and includes the device ID of the memory card, the public key of the IC memory card, and the signature data generated by the CA, and stores the received public key certification in the storage area.

Further, the IC memory card stores the public key released  
20 by the server 30, the public key released by the server 40 and the public key released by the server 50 in the storage area.  
(Service Subscription Request)

The following describes the processing performed by the control unit at the time when the IC memory card transmits the  
25 service subscription request to the server 30.

The control unit establishes the SAC with the server 30 with use of the RSA cryptosystem as the algorithm of the public

key cryptosystem. This SAC establishment is performed in the same manner as the SAC establishment in the above-described embodiments, and the processing performed by terminal device 10 in the embodiments is here performed by the IC memory card.

5 Using the SAC established between the IC memory card and the server 30, the control unit receives the system parameters " $a_1, b_1, p_1, q_1$  and  $G_1$ " from the server 30 via the terminal device.

The control unit generates the private key for service, and calculates the public key with use of the generated private 10 key for service and the system parameters. The control unit writes the generated private key for service into the secure area, and transmits the calculated public key to the server 30 via the terminal device, with use of the SAC established between the IC memory card and the server 30. After that, the control 15 unit receives the public key certification from the server 30 via the terminal device, and writes the received public key certification into the storage area.

The processing performed by the control unit at the time when the IC memory card transmits the service subscription 20 request to the server 40 is described next.

The control unit establishes the SAC with the server 40, and receives the system parameters for the elliptic curve " $a_2, b_2, p_2, q_2$  and  $G_2$ " from the server 40 via the terminal device, with use of the established SAC.

25 The control unit reads out the private key for service from the secure area, and calculates the public key with use of the read-out private key for service and the system parameters.

The control unit transmits the calculated public key to the server 40 via the terminal device, with use of the SAC established between the IC memory card and the server 40. After that, the control unit receives the public key certification from the server 40 via the terminal device, and writes the received public key certification into the storage area.

The processing performed by the control unit at the time when the IC memory card transmits the service subscription request to the server 50 is described next.

10 The control unit establishes the SAC with the server 50, and receives the system parameters for the elliptic curve " $a_3$ ,  $b_3$ ,  $p_3$ ,  $q_3$  and  $G_3$ " from the server 50 via the terminal device, with use of the established SAC.

15 The control unit reads out the private key for service from the secure area, and calculates the public key with use of the read-out private key for service and the system parameters. The control unit transmits the calculated public key to the server 50 via the terminal device, with use of the SAC established between the IC memory card and the server 50. After that, the control 20 unit receives the public key certification from the server 50 via the terminal device, and writes the received public key certification into the storage area.

In this way, the IC memory card can generate three different public keys corresponding to the servers respectively, with use 25 of the one private key for service generated at the time of transmitting the service subscription request to the server 30 and the system parameters received from the servers.

(Service Usage Request)

The following describes the processing performed by the control unit at the time when the IC memory card transmits the service usage request to the server 30.

- 5       The control unit reads out the private key for service, the public key certification (issued by the server 30) and the public key of the server 30 from the storage area, and establishes the SAC with the server 30 with use of the read-out key information. This SAC establishment is performed in the same manner as the
- 10      10 SAC establishment in the above-described embodiments, and the processing performed by terminal device 10 in the embodiments is here performed by the IC memory card. Note that the algorithm of the public key cryptosystem used in the SAC establishment processing is the elliptic curve cryptosystem.
- 15      15 The control unit receives the encrypted contents from the server 30 via the terminal device with use of the SAC established between the IC memory card and the server 30, decrypts the received encrypted contents and stores the decrypted contents in the storage area.
- 20      20 The processing performed by the control unit at the time when the IC memory card transmits the service usage request to the server 40 is described next. The control unit reads out the private key for service, the public key certification (issued by the server 40) and the public key of the server 40 from the
- 25      25 storage area, and establishes the SAC with the server 40 with use of the read-out key information.

The control unit receives the encrypted contents from the

server 40 via the terminal device with use of the SAC established between the IC memory card and the server 40, decrypts the received encrypted contents and stores the decrypted contents in the storage area.

5       The processing performed by the control unit at the time when the IC memory card transmits the service usage request to the server 50 is described next. The control unit reads out the private key for service, the public key certification (issued by the server 50) and the public key of the server 50 from the  
10 storage area, and establishes the SAC with the server 50 with use of the read-out key information.

15      The control unit receives the encrypted contents from the server 50 via the terminal device with use of the SAC established between the IC memory card and the server 50, decrypts the received encrypted contents and stores the decrypted contents in the storage area.

In this way, the terminal device in which the IC memory card is inserted and other devices can reproduce the contents acquired from the servers 30, 40 and 50.

20      (8) In the above described embodiments, the CA generates a different set of the parameters for each server, and transmits the generated set of the parameters to each server. However, the servers are not necessarily required to acquire the system parameters from outside, such as the CA. The structure in which  
25 the servers themselves generate the system parameters is acceptable.

In such case where the servers themselves generate the

system parameters, the terminal device generates the different public key for each server (provider). Therefore, the different ID may be allocated to each server, and the server may generate the system parameters based on the allocated ID.

5 (9) The present invention may be the methods described above. Also, the present invention may be a computer program that realizes the methods with a computer, and may be a digital signal that includes the computer program.

The present invention may be a computer-readable recording medium, such as a flexible disk, a hard disk, a CD-ROM, an MO, a DVD, a DVD-ROM, a BD (Blu-ray Disc), and a semiconductor memory, on which the computer program or the digital signal is recorded. Also, the present invention may be such a computer program or a digital signal, which is recorded on the recording medium.

15 The present invention may transmit the computer program or the digital signal via a network and so on represented by such as an electric communication line, a radio or wired communication line, and the Internet.

The present invention may be a computer system that includes a microprocessor and a memory, where the memory stores the above-described compute program, and the microprocessor operates according to the computer program.

20 Also, the program or the digital signal may be executed by other independent computer system, by transmitting the recording medium, on which the program or the digital signal is recorded, to the computer system, or by transmitting the program or the digital signal via the network and so on to the

computer system.

(10) The present invention also includes structures that combine any of the above-described embodiments and modifications.

5 Industrial Applicability

The information security system described above is usable in industries which distribute digitalized contents such as movies and music via broadcast, a network and so on, as a system in which a user uses a plurality of service providers.